Maine Prepares – 2015 - Introduction

- Welcome to this Maine Prepares Conference breakout session about dam safety for Communities. Thank you for being here.

- My name is Tony Fletcher, who, together with the MEMA Operations Director, Mark Hyland, our new Assistant State Dam Inspector (ASDI) Mr. Dan Taylor, our Planning & Research Associate (PRA) Ms. Tara Ayotte, administer the Maine Dam Safety Program (MDSP) in Maine.

- The goal of this presentation is to give you an over view of the interesting and important subject of dam safety.

- Four brochures and a copy of Maine Dam Safety Law (MDSL) are available as handouts at this meeting. We also have a FEMA DVD Manual if you are contemplating armoring your dam. If we have run short of any handout, leave your name and contact address.

- Some expressions are abbreviated after the expression. If you don’t know what an abbreviation is please ask.

- The maps associated with this presentation will be left on exhibition until lunchtime.

- I have a lot of slides, many of which I will gloss over. Anybody wanting a copy of some or all of this presentation, leave a written description of what you want and how I can get it to you.

Maine Preparedness Conference
Augusta Civic Center
April 22, 2015, at 8.30am

Dam Safety in Communities

By

Tony Fletcher PE
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Maine Department of Defense, Veterans and Emergency Management (MDVEM)
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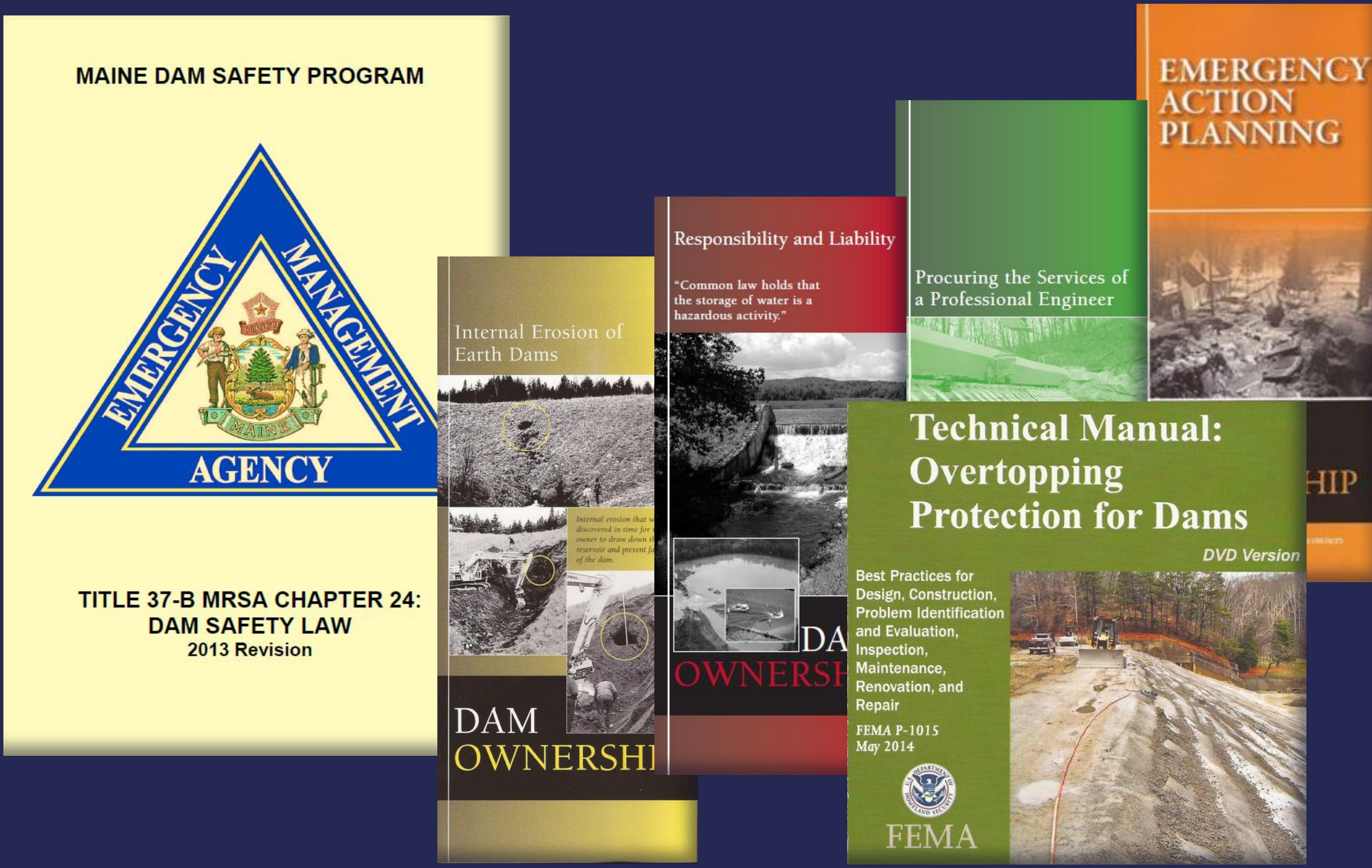
A MEMA Dam Success – Reconstruction of Canton Dam (Anasagunticook)

Handouts


MAINE DAM SAFETY PROGRAM
EMERGENCY MANAGEMENT AGENCY
MAINE
TITLE 37-B MRSA CHAPTER 24:
DAM SAFETY LAW
2013 Revision
Internal Erosion of Earth Dams
DAM OWNERSHI
Responsibility and Liability
"Common law holds that the storage of water is a hazardous activity."
DA
OWNERSH
Procuring the Services of a Professional Engineer
EMERGENCY ACTION PLANNING
HIP
Technical Manual: Overtopping Protection for Dams
DVD Version
Best Practices for Design, Construction, Problem Identification and Evaluation, Inspection, Maintenance, Renovation, and Repair
FEMA P-1015
May 2014
FEMA

Dam Safety Awareness

Why Dam Safety is of Concern to Communities

VIDEO-TADS- DAM SAFETY AWARENESS - Play 4.40m

Maine Office of Dam Safety – Ops Division - MEMA

- Maine Office of Dam Safety (MODS), falls under the Operations Division, of the Maine Emergency Management Agency (MEMA) which is an agency of the Maine Department of Defense, Veterans and Emergency Management (MDDVEM)

- Organization of MODS - 2.5 permanent staff positions consisting of:

  - State Dam Inspector (SDI) - Tony Fletcher PE – Full Time post – 207-592-4315
  - Assistant State Dam Inspector (ASDI) –Full time post – Dan Taylor – 207-299-2906
  - Planning & Research Associate (PRA) – Tara Ayotte – ½ time post – 207-624-4400
  - 1-2 summer interns a year

- Duties are to; implement Maine Dam Safety Law (MDSL); assess the hazard and condition of all State Regulated Dams (SRD's), facilitate Emergency Action Plans (EAP's) for SRD's, classify dams into high (HH) significant hazard (SH) & low (LH) and maintain a database.

- Funded jointly by the State of Maine and the NDSP, through a grant administered by FEMA (FY14 value $83,793). This grant supports salaries, transport, training, consultants and equipment for the program.

- Progress of the Maine Dam Safety Program is reported quarterly to FEMA, then annually to FEMA, the Maine Legislature and the Army Corps of Engineers.

Scope of the MDSP

- The State dam database contains 1,112 dams, of which;
- 823 (75%) are jurisdictional,
- 601 are regulated by DDVEM & 163 are regulated by FERC,
- 9 are located on the ME-NH border (Salmon Falls River) regulated by the Dam Bureau of the NH Department of Environmental Services (NHDES). A further 40 NH dams also regulated by the NHDES, drain toward ME.
- 2 dams (Woodland and Grand Falls), located on the Canadian border, are regulated by State, FERC and the International Joint Commission on dams (IJC),
- 9 dams are yet to be classified.

Status of Dams in ME & the Condition of SRD’s

- Table 1 – EAP Status of Dams in ME.
- Table 2 – Indication of the conditions of HH & SH State regulated dams based on a “rapid assessment survey” done in 2011.

Table 1 – Dams in ME & Their EAP Status

TABLE 1	Maine Dam Safety Program (MDSP)			FERC Regulated Dams in ME			NH DES Dams that could affect ME		
Hazard	# Dams	# EAP's	% EAP's	# Dams	# EAP's	% EAP's	# Dams	# EAP's	% EAP's
High	28	28	100%	33	33	100%	19	19	100%
Significant	75	70	93%	9	9	100%	30	20	67%
Low	499	Not required	0%	121	32 (7)	100%	10	4	44%
Total	602	98		163	47		59	43	

Table 2 – Indication of the Condition of HH & SH SRD's 2011/12

Dams		Condition of Inspected Dams		
Dam Hazard	**Number of Dams**	**Satisfactory**	**Fair**	**Poor**
High	**27**	10	13	**4**
Significant	**72**	21	24	**25**
Totals Assessed	**99**	31	37	**29**
% SRD's Which Require EAP's		31	38	**29**
Low	**505**	In terms of State Dam Safety Law – Title 37B c24 low hazard dams do not require condition inspections		

Dam Safety Law

The Foundation of State Dam Safety Programs in the US

The National Dam Safety Program (NDSP)

- The foundation of modern day dam safety can be found in US Federal Law PL 92-367, approved by Congress on Aug 8, 1972, which authorized the Secretary of the Army, through the Corps of Engineers, to undertake a National Program of Inspection of Dams (NPID), to protect human life and property. This law followed failure of Buffalo Creek Dam.

- The NPID led to the creation of the National Dam safety Program (NDSP), funded by Congress and administered by FEMA. The NDSP is a partnership of the states, federal agencies and other stakeholders that encourages individual and community responsibility for dam safety.

- To determine whether a dam, including waters impounded by such a dam, constitutes a danger to human life or property, Sec. 4. of Federal Law PL 92-367, states that the Secretary shall take into consideration the possibility that the dam might be endangered by the following;

- overtopping, seepage, settlement, erosion, sediment, cracking, earth movement, earthquakes, failure of bulkheads, flashboard, gates on conduits, or other considerations which exist or which might occur in any area in the vicinity of the dam. (These are the things we look for when assessing the “condition” of a dam).

- In ME, a Dam Condition Assessment (CA) is preceded by a Hazard Assessment (HA) which limits CA’s to High and significant potential hazard dams only.

Maine State Dam Safety Law (MDSL – Yellow Booklet)

- State law governing the safety of dams in Maine is;
- Title 37B MRSA Chapter 24, Dam Safety.
- This Law assigns regulation of SRD’s to MDDVEM, with duties to;
  - Inspect existing dams and reservoirs to determine their potential hazard
  - Review the design and construction of new and reconstructed dams
  - Assist dam owners develop emergency action plans (EAP’s) to minimize the effect of dam failure
  - Take all necessary precautions in emergency situations at dams to protect life and property.

Dams

Definitions, Types & Forces

Definitions

- Dam a water retaining structure, normally built across river valleys to supply, store or divert water for useful purposes. In order to control river flows, spillways and pipe outlets are set in the dam to pass storm flows using gates and valves. Dams may be constructed of wood, stone, soil, rock, concrete, steel, and many have hydroelectric power generation systems installed.

- A road embankment is not a dam unless a dam has been built into the road culvert. The origin of the word “dam” is Dutch – Rotterdam, Amsterdam, etc.

- Appurtenant Works of a dam are all features additional to the dam such as gates, spillways, conduits, power houses, roads, and the like.

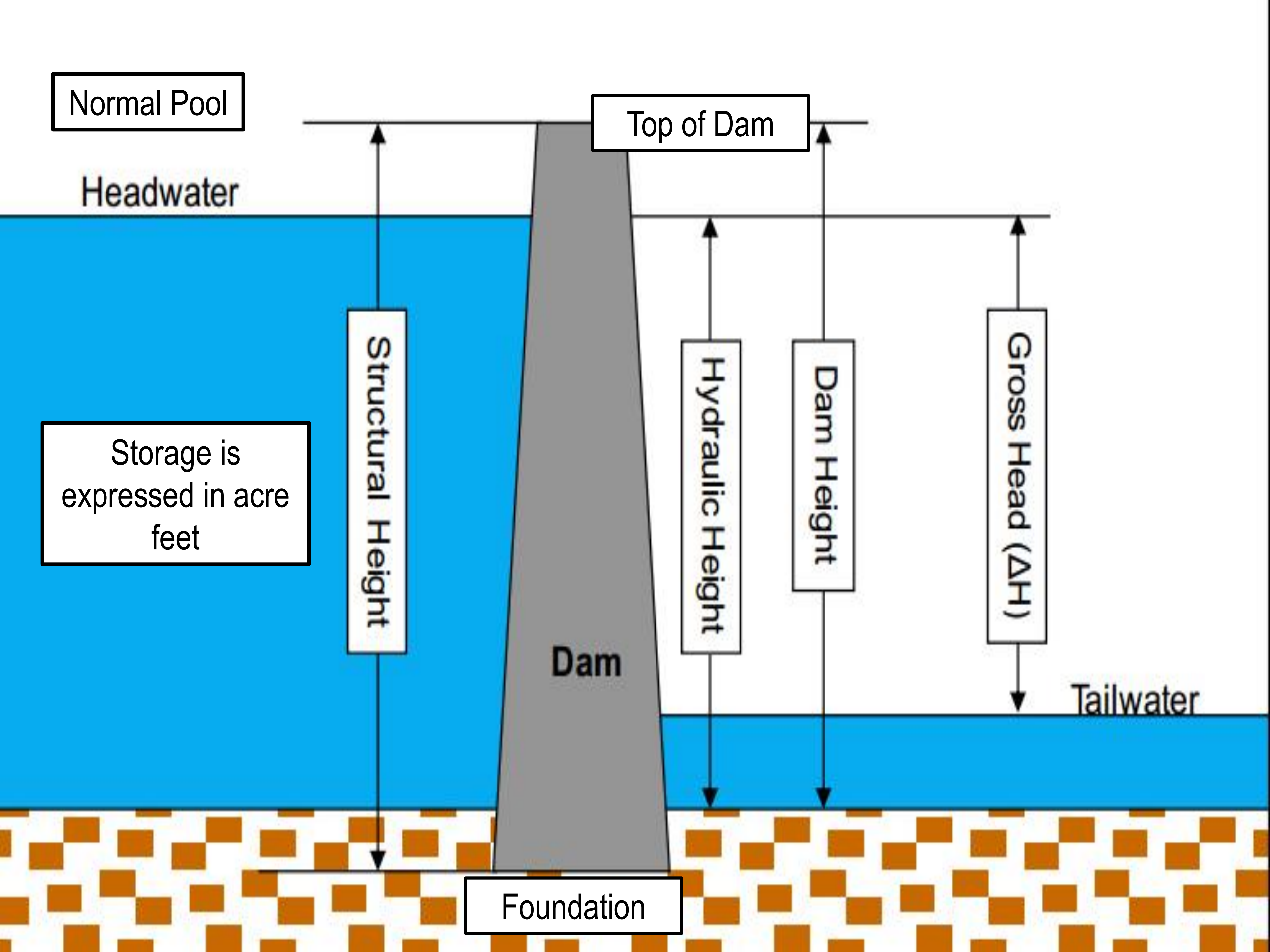
- Top of Dam (TOD) is the horizontal non overflow portion of a dam sometime expressed as an elevation.

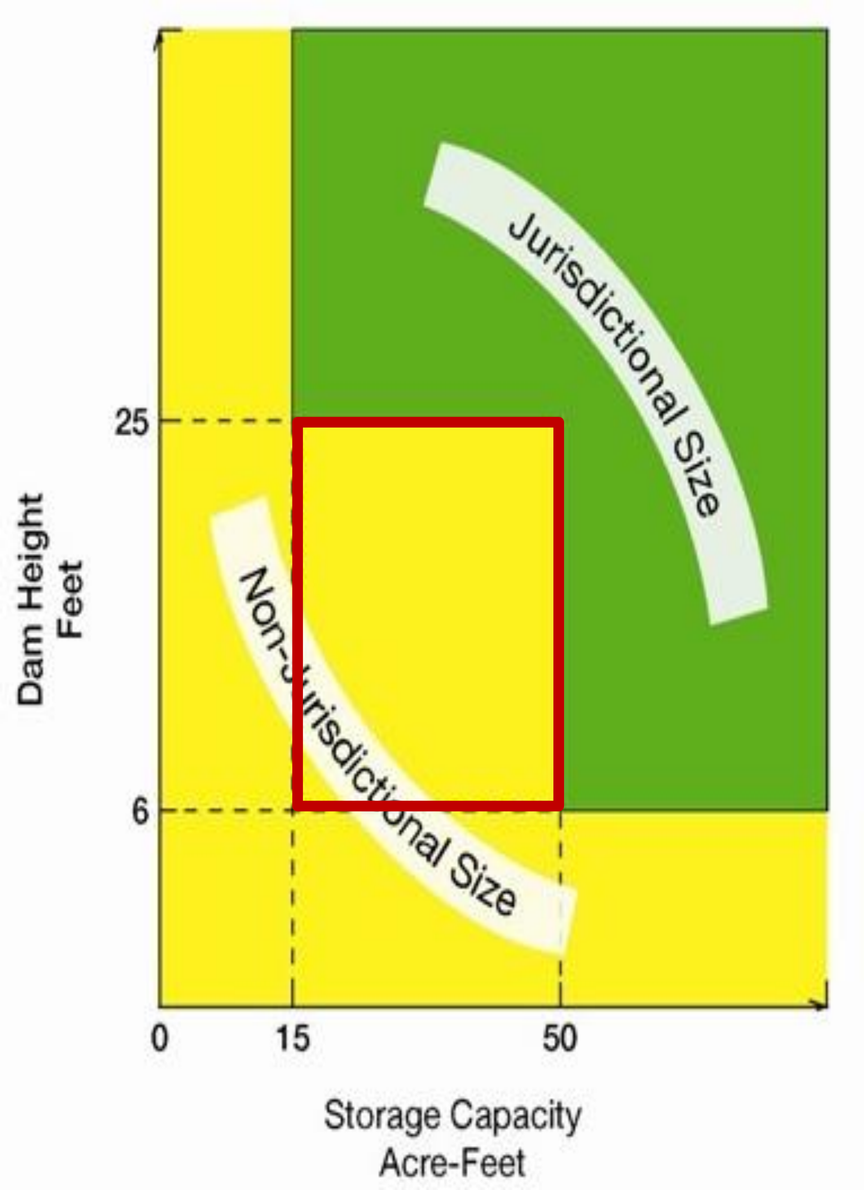
- Length of a dam is the horizontal distance measured along the TOD between abutments.

- Normal Pool (NP) is the normal operating level of the lake expressed as an elevation – also head-pond level

- Freeboard = (TOD – NP) measured vertically in feet

- Height of Dam (H) is the vertical distance between TOD and the lowest point at its toe.


Normal Pool
Top of Dam
Headwater
Storage is expressed in acre feet
Structural Height
Hydraulic Height
Dam Height
Gross Head (ΔH)
Dam
Tailwater
Foundation

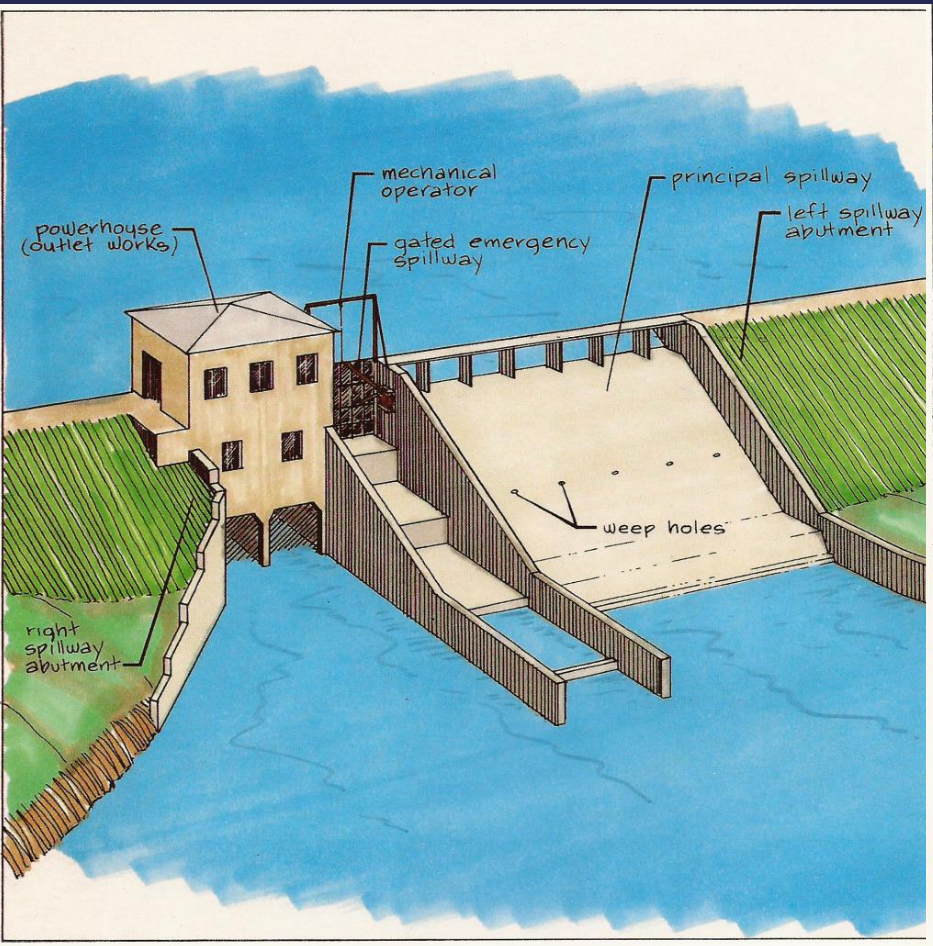


- Jurisdictional Dams those > than 25' in height, storing more than 15 acre-feet; and those > 6 feet in height, storing more than 50 acre-feet. (1 acre foot = 203,860 gallons or 2.72 million pounds)

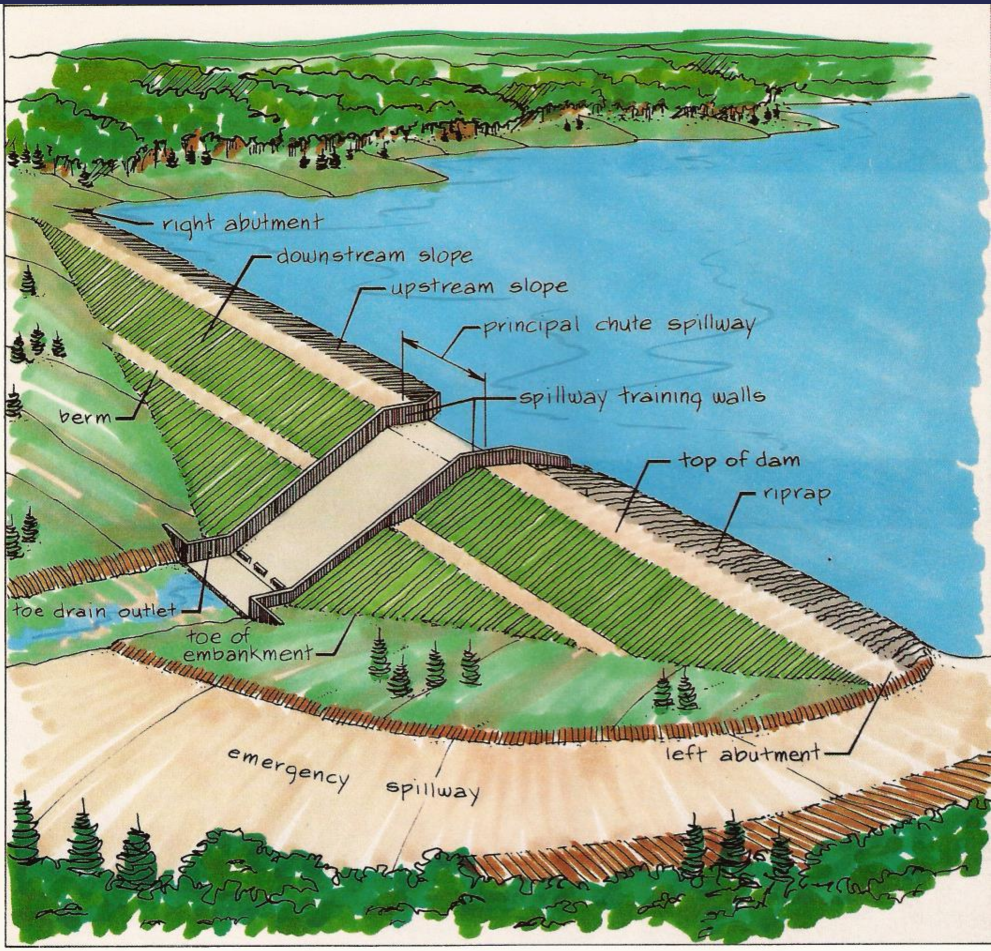
- Normal Storage – is the useful volume of water impounded by the dam at normal pool. About half the NP area multiplied by dam height.

- Potential Energy Stored in a Dam - is indicated by the product of the dam height and its storage. That would also be its generating potential.

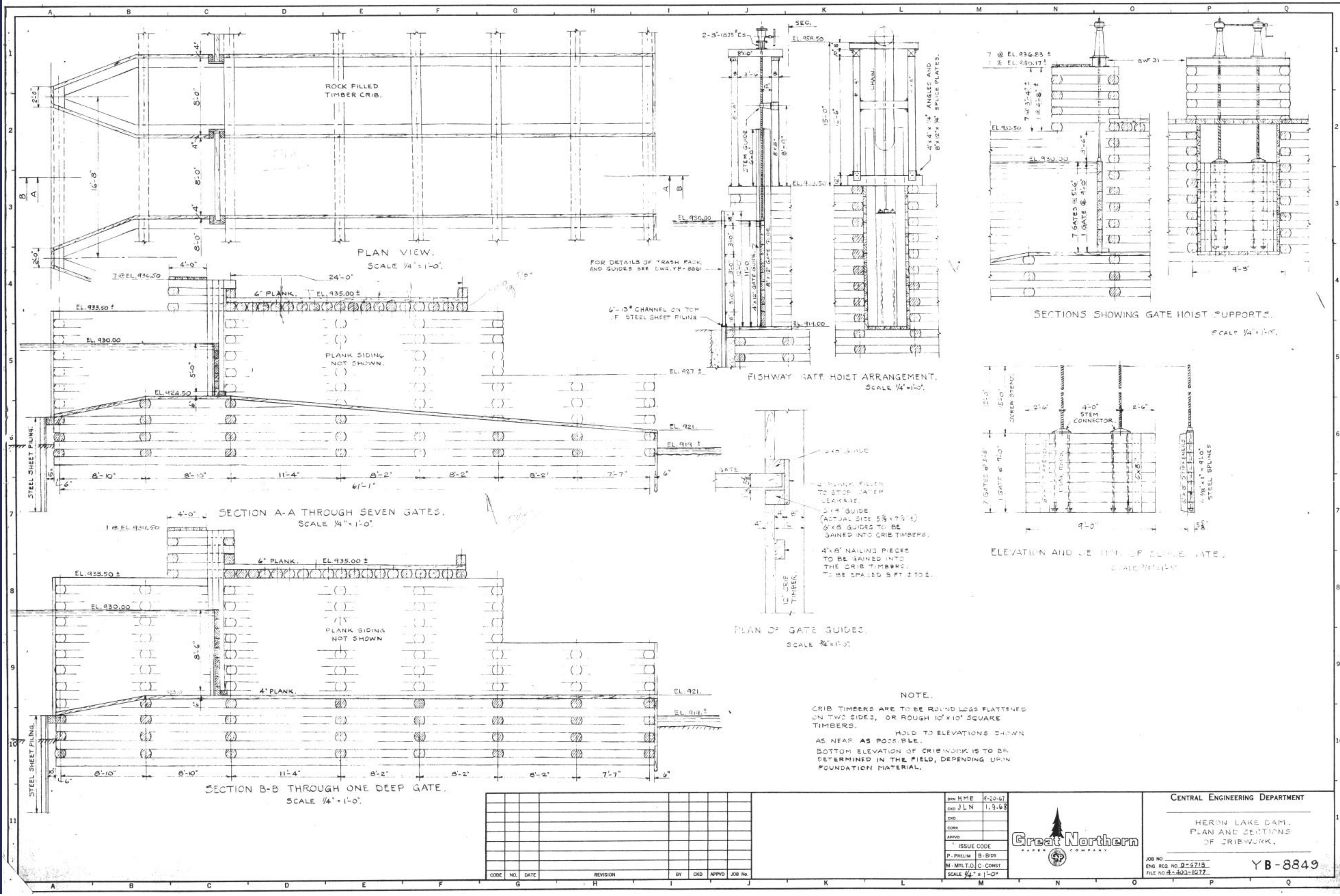
Principal Parts of a Dam



principal parts of a dam



principal parts of a dam



ROCK FILLED TIMBER CRIB.
PLAN VIEW.
SCALE 1/4" = 1'-0".
FOR DETAILS OF TRASH RACK AND GUIDES SEE DWG. YP-8861
6"-13# CHANNEL ON TOP OF STEEL SHEET PILING
FISHWAY GATE HOIST ARRANGEMENT.
SCALE 1/4" = 1'-0".
SECTIONS SHOWING GATE HOIST SUPPORTS.
SCALE 1/4" = 1'-0".
6" PLANK.
EL. 935.00 ±
EL. 933.50 ±
EL. 930.00
PLANK SIDING NOT SHOWN.
STEEL SHEET PILING.
EL. 921.
EL. 919 ±
61'-1"
SECTION A-A THROUGH SEVEN GATES.
SCALE 1/4" = 1'-0".
ELEVATION AND SECTION OF SLUICE GATE.
PLAN OF GATE GUIDES.
PLANK SIDING NOT SHOWN
4" PLANK.
SECTION B-B THROUGH ONE DEEP GATE.
SCALE 1/4" = 1'-0".
NOTE.
CRIB TIMBERS ARE TO BE ROUND LOGS FLATTENED ON TWO SIDES, OR ROUGH 10"x10" SQUARE TIMBERS.
HOLD TO ELEVATIONS SHOWN AS NEAR AS POSSIBLE.
BOTTOM ELEVATION OF CRIBWORK IS TO BE DETERMINED IN THE FIELD, DEPENDING UPON FOUNDATION MATERIAL.
CODE NO. DATE REVISION BY CKD APPVD JOB No.
DRN H M B 4-20-67
CKD J L N 1.9.68
ISSUE CODE
P-PRELIM B-BIDS
M-MTL T.O. C-CONST
SCALE 1/4" = 1'-0"
Great Northern PAPER COMPANY
CENTRAL ENGINEERING DEPARTMENT
HERON LAKE DAM.
PLAN AND SECTIONS OF CRIBWORK.
ENG. REQ. NO. D-6719
FILE NO. 4-400-1077
YB-8849

1. Telos dam from 400' right

2. Telos dam from downstream right bank – one gate open

3. Telos Dam gate #6

4. De-commissioned Radial Gate from pier &2

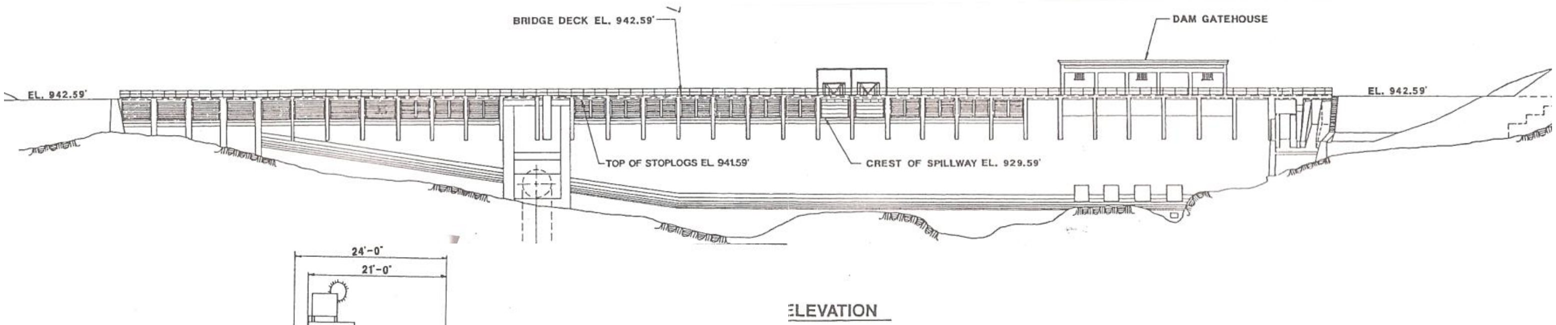
5. Telos dam pier #2 upstream

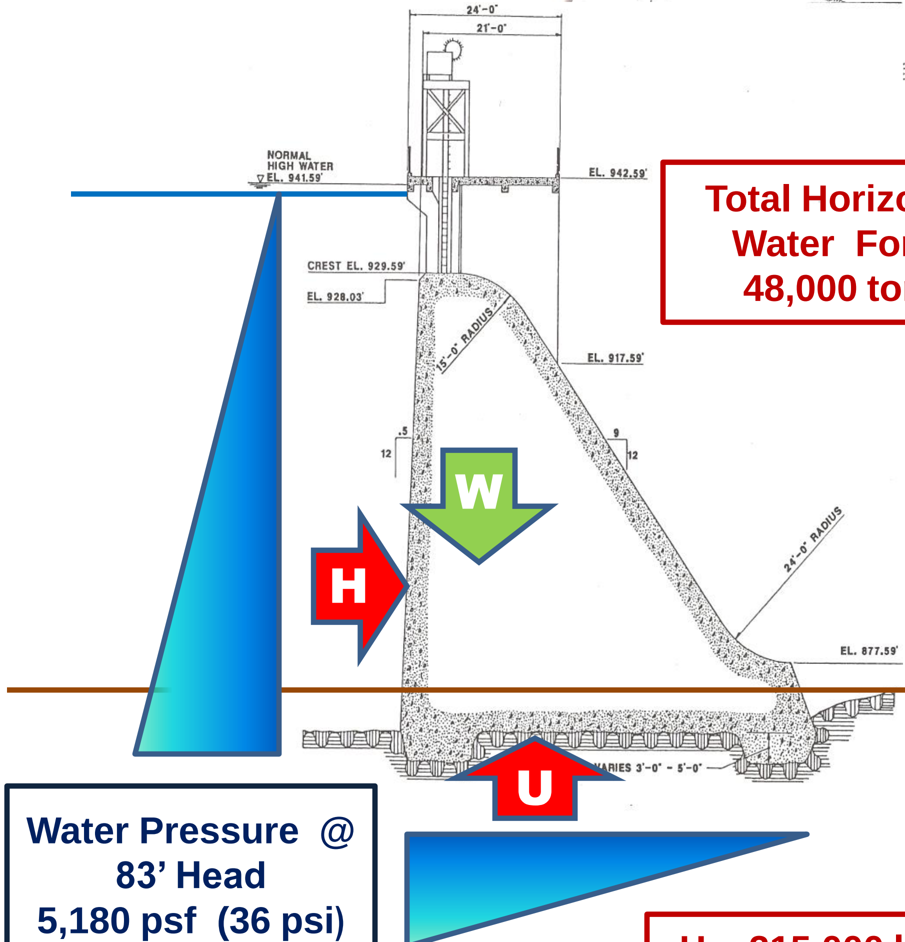
#41 Telos Dam

Type:
20' High, 240' Long
Timber Crib Rock
Ballasted Dam
(Mass-gravity)

Defects:
Wood Rot
Pier Movement

Gravity Forces Acting on a Dam





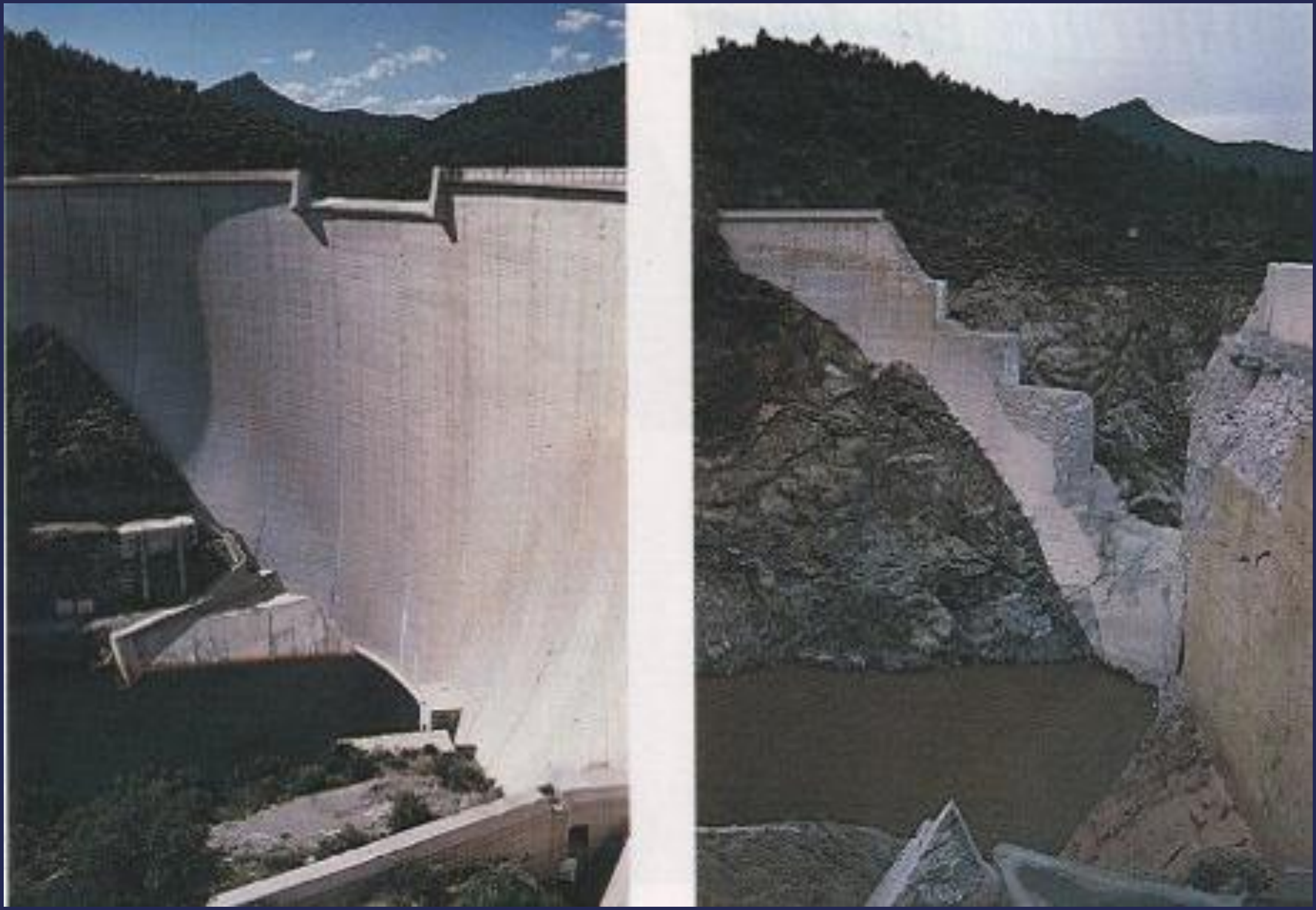
Total Horizontal Water Force 48,000 tons

Water Pressure @ 83' Head 5,180 psf (36 psi)

H = 215,000 lbs/ft
U = 155,000 lbs/ft

Example - Ripogenus Dam
Concrete Mass Gravity 83' High, 780' Long

Malpasset Dam Failure



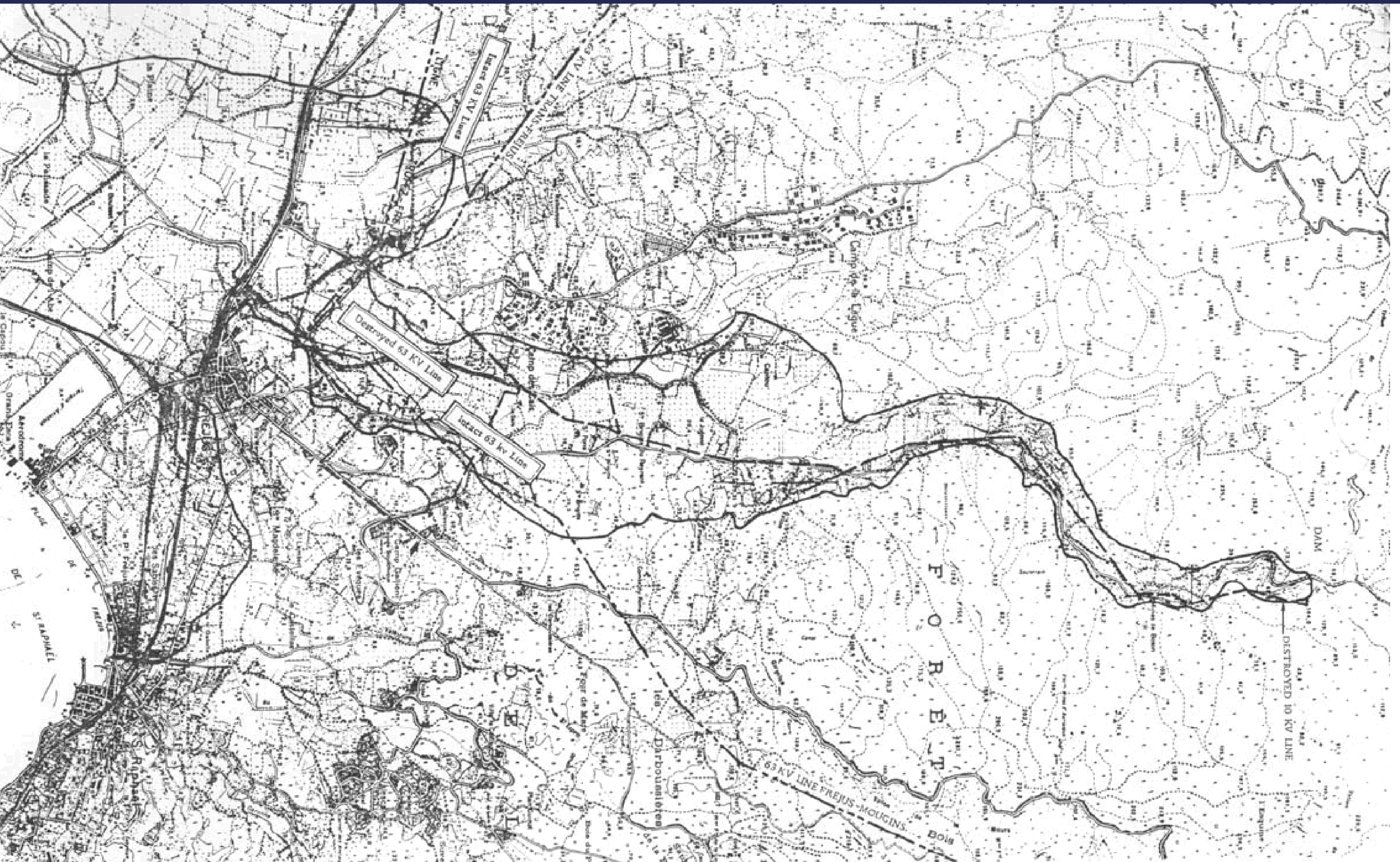
Cause of failure - attributed to undetected faults in the foundation. Other factors; deficient geological survey, concrete design stresses highest ever used in concrete arch dam. Dam owner held back on opening bottom outlets during floods, dam near over-topping when opened. No emergency action plan or downstream inundation map.

Malpasset Dam

Loss of life 423. Damages $58 million.

- Failed Dec 2, 1959 at 9.13 pm, lake was within a foot of the TOD. The resultant 130' high flood wave, of about 1,420,000 cfs, swept down the valley at 44 mph (65 fps), completely destroying two small villages (Malpasset, Bozon) and a highway construction site.
- 20 minutes later a 10' wall of water entered the western part of the town of Fréjus on the French Riviera (Côte d'Azur) before flowing into the sea. Roads, railroads, transmission lines, industrial areas, vineyards, farms, etc. were also destroyed.
- 200' high, 720' long, concrete arch, 22' wide at the base and 5' wide at the top, constructed between 1957 and 1959 storing 41,000 af.
- Dam had bottom outlets with a max discharge of 1,320 cfs. The emergency spillway was a 100 wide weir at the top.
- Construction beset by financial and labor problems.
- The dam had no EAP.

Malpasset Dam – Downstream Inundation



The accidental release of water downstream of Malpasset Dam resulted in devastating;

- ❑ Loss of Life -
- ❑ Property Damage – houses, buildings, roads, businesses, etc.
- ❑ Environmental damage – erosion, habitat loss, deposition of soil and debris, etc.
- ❑ Economic Losses – water supply, road and rail, power generation, power distribution, navigation, etc.
- ❑ Clearly communities which would be affected by such a breach, as many are in Maine, have to;
    - ❑ Be informed of the dangers associated with a dam upstream of them,
    - ❑ Be consulted about the dam EAP,
    - ❑ Be involved with any Test of that EAP

"Of all the structures built by human hands, dams are the most deadly."

André Coyne

Engineer of the Malpasset dam, and President of the International Committee on Large Dams (ICOLD), undisputed specialist in the construction of arch dams, who died six months after Malpasset dam failed.

I have used this example to illustrate that dam's, designed and built with the best of intentions, can and do fail catastrophically

Emergencies at Dams

Planning for Dam Failure

“A Failure to Plan is Planning to Fail”

“We don’t have a Plan – so nothing can go wrong” (Spike Milligan)

Planning

- Planning (also called forethought) is the process of thinking about and organizing the activities required to achieve a desired goal.

- Planning involves the creation and maintenance of a plan, such as psychological aspects that require conceptual skills.

- There are even a couple of tests to measure someone’s capability of planning well.

- Planning is a fundamental property of intelligent behavior.

Emergencies, Repairs and Engineering

- Emergency means breaches and all conditions leading to or causing a breach, overtopping of a dam and its appurtenant structures that may be construed as unsafe or threatening to life and property.

- Emergency situation means a situation determined by the commissioner, to present a potential but real and impending danger to life, limb or property because of flooding or potential and imminent flooding

- Emergency Action Plan (EAP) means a set of written instructions or guidelines for use by public officials that recommends actions that, when implemented, will minimize the effects of a dam failure on people and property.

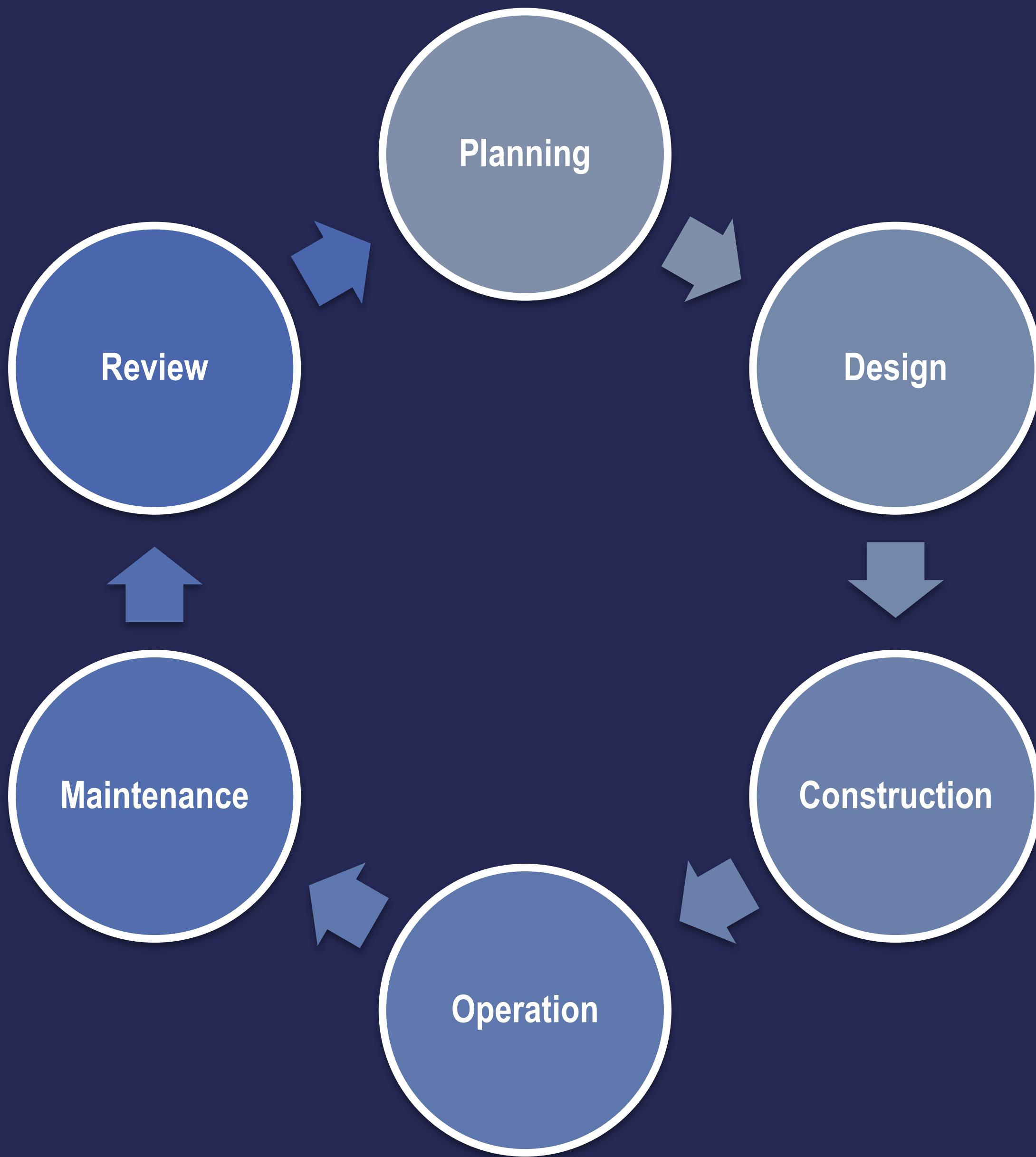
- Necessary Remedial Measures (NRM) means any repair or hazard-reducing measure relating to a structural component or operation of a dam needed to mitigate a specific condition at the dam that constitutes a threat to public safety.

- Engineering is concerned with the prevention of failure, a word associated with breakage and loss. The failure of an engineered project is when it ceases to function as designed. Failure can occur at any phase of a project from concept to its operation. “Dam failure” would be an “emergency” as defined above. Functional failure is when a dam cannot pass a flood. Structural failure is when a dam cannot withstand the loads imposed on it. When a dam fails the danger is always the possible release of water downstream.

Notions About Dam Safety & Hazard Potential

- Safety means security from harm or danger.
- Dam Safety is a program of control which recognizes hazards at dams, and then achieves acceptable levels of protection for people and property. Ensuring a dam is planned, designed, constructed, operated and maintained (diagram) in such a way that its risk to life, health and property is minimized.
- Failure generally means inability to perform a normal function, abrupt cessation of normal functioning, a fracturing or giving way under stress.
- Dam Failure means not meeting desirable standards of planning, design, construction, operation or maintenance.
- The likely outcome of dam failure is the unplanned release of water from a dam or its appurtenances, and in the worst cases creating a flood which kills and destroys leading to liability lawsuits against the dam owner, their agent and all dam inspectors.
- Common law holds that the storage of water is a hazard. It also holds that the owner of the dam is responsible for any release of the contents of a reservoir.
- A tort, is a common law civil wrong that unfairly causes someone else to suffer loss or harm, leading to liability.
- Tort law is the law of loss and compensation, likely to come into effect through trial lawyers seeking compensation after losses caused by dam failure.

Dam Safety in the Engineering Project Cycle



The Potential Hazard classifications of dams in Maine

- The “Hazard” assigned to a dam in ME is a general measure of its potential to take life and cause damage if it failed. Hazard does not an indication of the physical condition of the dam.
- Dam Hazard Classes;
- High Hazard Potential (HH) - failure directly threatens human life
- Significant Hazard Potential (SH) – failure threatens property, the environment with little threat to human life
- Low hazard potential (LH) – failure damage limited to dam only.
- HH & SH dams in ME require emergency action plans (EAP’s)
- This classification does not mean that SH or LH dams cannot take life or cause property damage if it failed. They can and they have.
- Other classifications used in MODS are ;
  - “N” meaning the dam is non-jurisdictional,
  - “U” which means unclassified, pending a HA.

Dam Maintenance

The First Step to Keeping a Dam in Good Condition

VIDEO-ASDSO-DAM MAINTENANCE-1:49 m

Routine Dam Maintenance of Dams

Keeping a dam in good condition is important and can prevent problems that lead to failure. Maintenance must be performed routinely so that minor problems do not become major. Maintenance actions include the;

- Maintenance of gates and spillways in working order. Remove debris, ensure gates are fully operational, thus ensuring maximum discharge during floods.
- Control of brush and trees growing on or near a dam because;
  - Heavy vegetation makes inspection difficult,
  - Vegetation can block spillways and outlets,
  - Vegetation can provide a haven for burrowing animals,
  - Trees can be blown over, uprooting parts of the dams structure.
- Removal of burrowing animals living in an embankment because their activities shorten internal seepage paths, increasing the potential for internal erosion and dam failure.
- Removal of beavers living near a dam because they are attracted by flowing water and tend to block spillways and outlets with dams and lodges.
- Control of surface erosion of embankment surfaces with grass or rip-rap. Replace rip-rap if needed to mitigate wave erosion of the shoreline.
- Repair of sloughs and slides found on a dam, to prevent water infiltrating into the dam and improve dam stability.

Failure of Nash's Lake, Calais, ME

EAP Development

Video

&

Making an EAP

Mitigating the Effects of the Failure of their Dam

What a Dam Owner needs to do;

- Examine the dam, its location.

- Examine the way it is maintained and operated.

- Formalize a plan to lessen the effects of any emergency at the dam including that most unfortunate of all failures – its breach.

- This act alone means that the dam owner has considered what would happen if their dam failed and is taking the necessary steps to protect the public from injury and damage. This would be mitigating evidence in a court of law during litigation

- It also means a dam owner can respond in a responsible way to any emergency at the dam

VIDEO-TADS-EAP DEVELOPMENT-10:0 m

Making a Dam EAP

- ❑ 1) Visit your dam with the State Dam Inspector (SDI), discuss ways it may fail.

- ❑ 2) Using USGS “topo-quads” make a map showing 6 miles of river valley downstream of the dam. Examine the area and circle infrastructure that could be impacted by a breach wave in red. Time is of the essence in a dam emergency, so also make a preliminary estimate of the time the breach wave will reach roads and buildings, a mile every 5 minutes is 12 mph. (Some breaches are considerably faster, but it’s a good start at conceptualizing) If you can, determine a reasonable breach flow and approximate its impact at these control points. To sketch the “dam breach flood zone” on your map you may need a little help.

- ❑ 3) Now visit all the areas marked on the map. Look for additional houses and buildings along the riverbanks which could be damaged by a breach. Look for low lying areas along the river where lakes may form. Measure the opening of each bridge and culvert and record it.

Dam Emergency Action Planning

- 4) Invite the State Dam Inspector and all officials who will respond to an emergency to meet at the dam. Discuss failure modes their and expected breach flow. Then visit all downstream areas vulnerable to dam breach flooding. Now meet across a table, and using your draft dam breach inundation map (DBIM), agree on a specific plan of action to facilitate a response to an emergency at your dam. At the same time begin to develop the “notification flowchart” (NF) to facilitate communication and management of the emergency.

- 5) Agree the primary communication systems with officials. In emergency situations, phones & email can fail. Decide what backup systems are available. It’s a good idea to always be in touch with the dispatcher, no matter what the means of communication.

- 6) List all parties to the EAP on your NF, in the order they would be called. At minimum show the contact name, number, organization and clearly define their role in the emergency process.

Dam Emergency Action Planning

- 7) The DBIM and NF are the heart of a dam EAP, and must always be up to date. The worst thing to have during an emergency at a dam is outdated information.

- 8) The most important thing is to save lives during an emergency and this must be the basis of the plan. So it should show sufficient detail to facilitate evacuation road closure during an emergency. Evacuation lists should show the names and addresses of people impacted by a breach. Full community involvement is recommended for this aspect of the plan.

- 9) Develop a rough draft of the EAP using the DBIM and NF. Make sure it is clear and easy to follow and include appropriate messages. Copy the rough draft to all participants for review, have a public meeting. Support from the public will strengthen your plan. Finally, include all feed back into the plan, test it, then send a signed copy of the plan to each party. Ensure the plan has sufficient information in it so that it is seamless with the next phase of emergency management, that is recovery.

Dam Emergency Action Planning

- 10) The following are recommended dam EAP “activation levels” which should be specified in the EAP;
  - Level 1 (READY) means always keeping communication lines open and testing them regularly. A dam EAP, once agreed, should always activated yo “Level 1”.
  - Level 2 (SET) means notifying everybody of am emergency situation at a dam and be prepared to go to level 3.
  - Level 3 (GO) means mobilization and evacuation.
- 11) Always update the plan. When changes are made, like contacts and numbers, pencil them into the document, then copy it to all holders of the plan.

Development of Dam Breach Inundation Maps (DBIM's) & County Dam Maps by MEMA

General Requirements of DBIM's

- The purpose of a DBIM is to provide clear and sufficient ground and breach information, to enable a group to adequately plan for an emergency at the subject dam. It is at the heart of a dam EAP and must contain specific information to facilitate an emergency.

- It is important that the DBIM be a coherent and reliable source of information for emergency planning.

- The map should clearly show a grid, contours, natural features, roads, houses, buildings, pipelines, and the anticipated dam breach flood line, to a scale that is easy for a group to read around a table.

- Later details incorporated on the DBIM should be evacuation routes, shelters, fire stations, schools, and the like. The DBIM should be used as the basis of evacuation and road closure planning.

- The map should be updated regularly as new information is found.

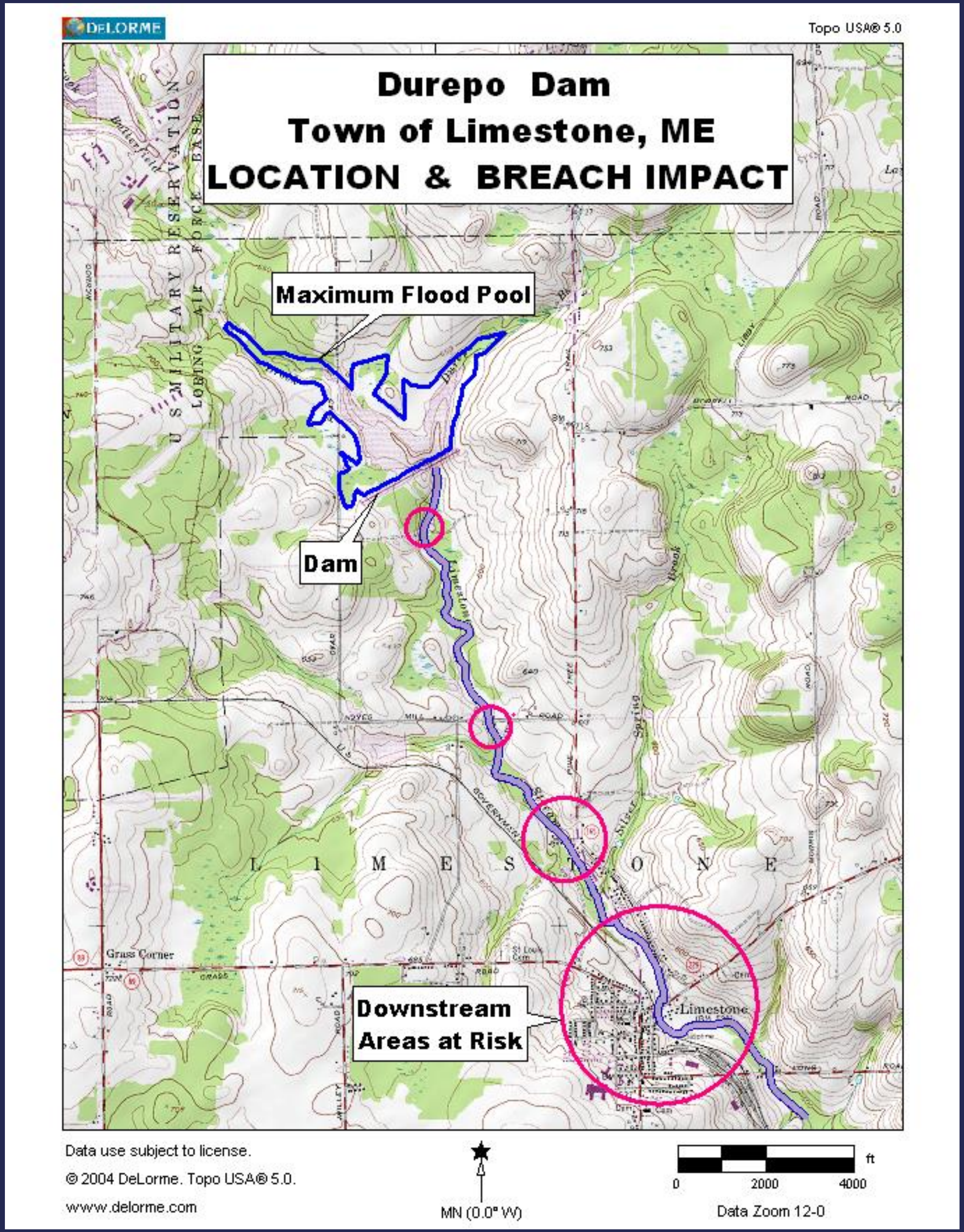
DBIM’s

- What we found at MEMA was that DBIM’s submitted with each EAP are inadequate to plan and implement an emergency at a dam. Most maps lack the basic detail necessary to plan for an emergency.

- To obviate this situation, MODS has developed a GIS mapping capability to make coherent and standardized DBIM’s for all SRD’s that require them.

- About 9 months ago, Mr. Dan Taylor joined the MDSP as the ASDI. With his GIS experience, he has developed two GIS maps. The first is an emergency planning map for incorporation into EAP’s for SRD’s, eventually to be used as DBIM’s, the second is a dam information map for County EMA’s.

- The following slides begin with the DBIM produced by MODS to supplement data in current EAP’s. This is followed by the prototype of the DBIM Silver Lake Dam, compared with its extant map supplied by the dam owner. After that is a prototype of the County Dam Information Map developed for York County.


DeLORME
Topo USA® 5.0
Durepo Dam
Town of Limestone, ME
LOCATION & BREACH IMPACT
Maximum Flood Pool
Dam
Downstream
Areas at Risk
Data use subject to license.
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www.delorme.com
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2000
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Data Zoom 12-0

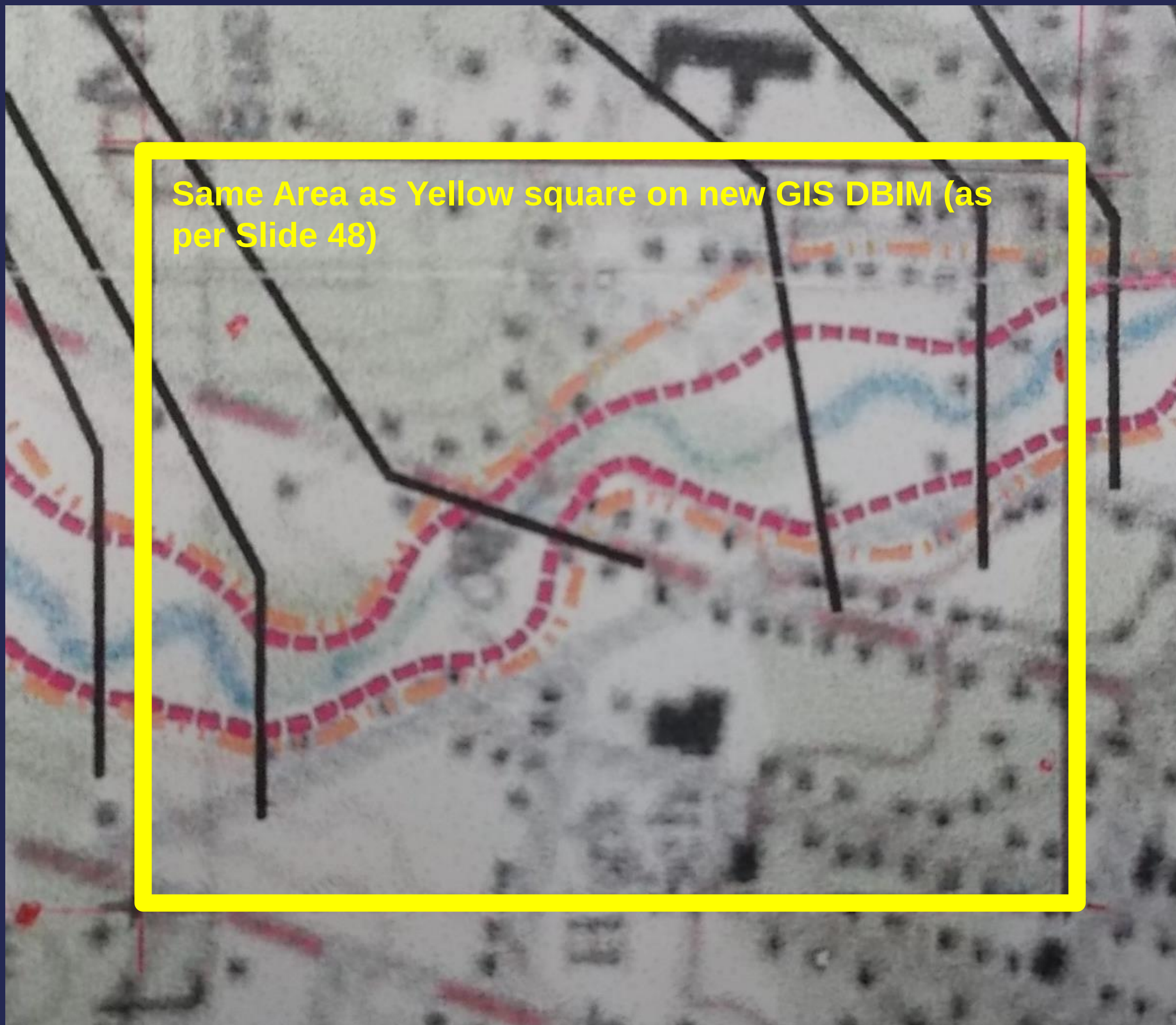
Comparing the Current and new DBIM's for Silver Lake Dam

GIS Dam Breach Inundation Maps for Silver Lake Dam, Bucksport, Hancock County, ME

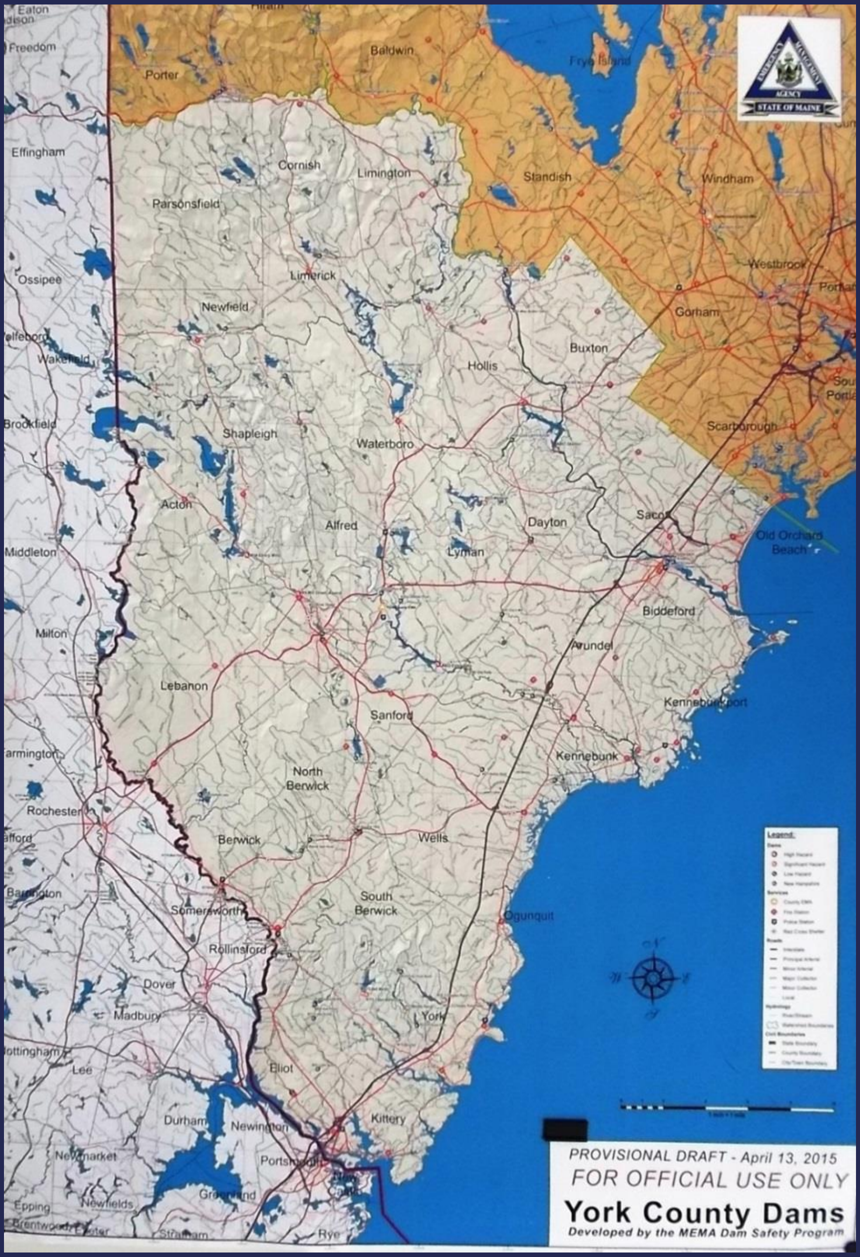
Comparative size of extant and proposed emergency planning maps for Silver Lake dam

Enlargement (Yellow Square) from new GIS DBIM for Silver Lake Dam

Enlargement (Yellow Square) from extant DBIM for Silver Lake Dam



GIS DBIM for Silver Lake Dam



Dam Failure

All Dams between 1900-1975
Type & Percentage

1) Overtopping 34%
2) Foundation 30%
3) Piping & Seepage 28%
4) Other 8%

Dam Failure

- As stated in the video earlier, a dam is one of the most potentially destructive engineering works of man, further, the un-controlled release of water from a reservoir can cause a flood wave downstream that has the force to destroy everything in its path.

- Dam failure can damage; buildings, water supplies, roads, railroads, gas & power infrastructure, pipelines, and the like. In addition it may cause environmental damage in the form of erosion, habitat loss, deposition of soil and debris, etc.

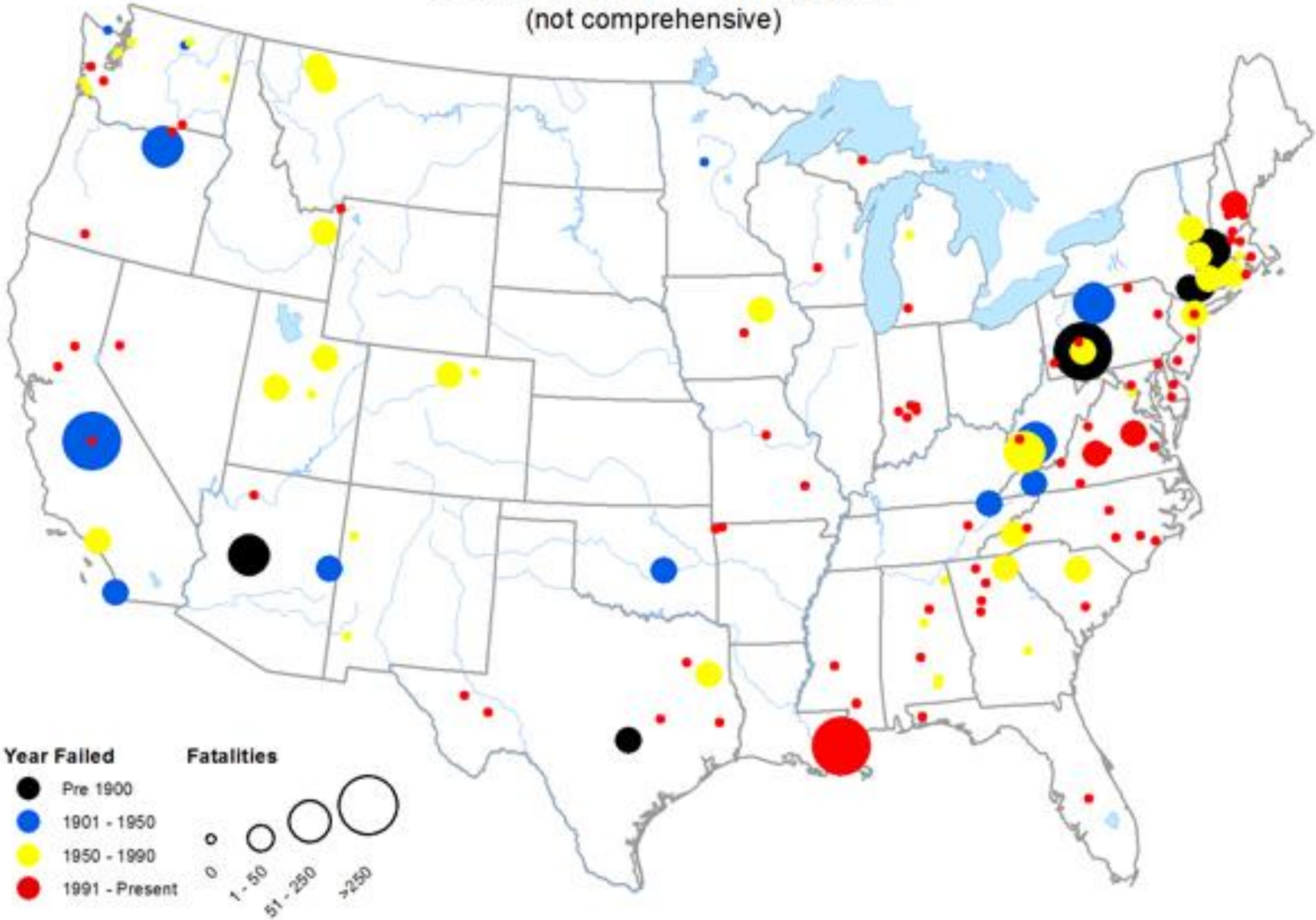
- Simply put – a failed dam can cause immense devastation - all of which costs the individual and community resources such as lives, property and time. Even a small dam has the power to take life and damage property.

- The general statement of liability is that if a water escapes from a dam, the dam owner is responsible

- So what is the extent of dam failure in the US? The next slide shows dam failures and associated fatalities in the US. This map illustrates the extent and regularity of dam failure in the US.

USA Dam Failures

(not comprehensive)



Foundation & Stability Failure

VIDEO-ASSDSO-INSTABILITY FAILURE 1.53m

Gleno Dam, Italy

Failed - 6:30 am 12/1/1923 (first filling)

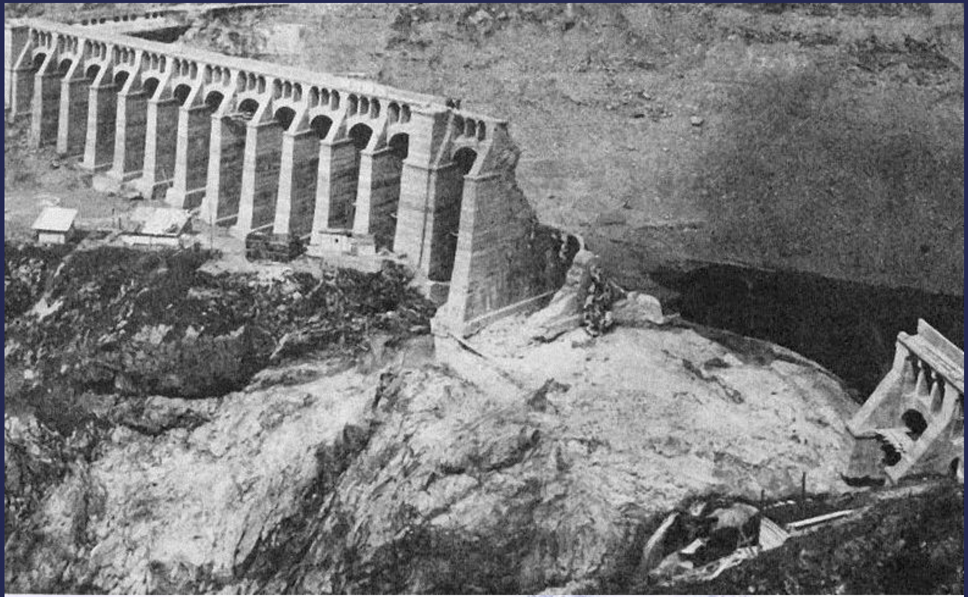
Deaths - 356 at least

Flood - Dam elev. 5,036 ft. 3,648 acre feet of water released which flowed through four villages (Bueggio, Dezzo, Colere, Corna di Darfo), then into Lake Iseo, elev. 610 ft.

Cause – Buttress collapse attributed to;

Design, material & construction deficiencies.

Remarks - To save concrete, the design was changed from MG to arch buttress. Weak concrete containing scrap WW1 anti-grenade netting as reinforcement. Workers that reported poor workmanship were fired.

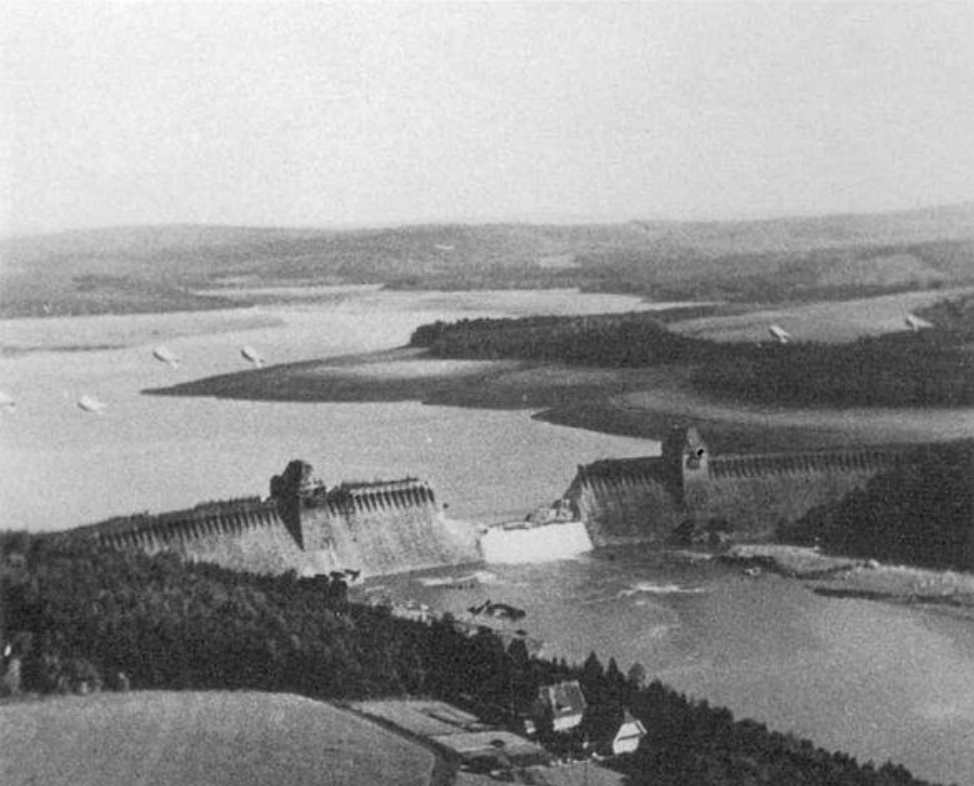


Gleno Dam Community Impact - Village of Colere

Dam Breach

by

Act of War



Möhne Dam, Germany

Built 1908 – 1913 to control floods, regulate water levels on the Ruhr, generate hydro power.

Storage 109,000 af.

Breached by RAF Bombers 16 May 1943 using 9,250 lb bouncing bombs containing 6,600 lbs Torpex.

Breach; 260’ wide, 73’ high hole blown into the dam flowing at 484,000 cfs.

The resulting dam breach flood killed at least 1579 people.

The city of Neheim-Hüsten was particularly hard-hit with over 800 victims

Overtopping Failure

Generally Caused by an Inadequate Spillway

VIDEO-ASDSO-OVERTOPPING FAILURE -0:56

Apple Valley Dam, North Monmouth, Kennebec County, ME

- Failed - April 17, 1977 (spring runoff).
- Estimated breach flow 1,400 cfs
- Estimated Damage – $150,000 to roads & houses, no loss of life.
- Mode of Failure - Blocked principal spillway, no emergency spillway, dam overtopped, cutback erosion of the embankment.
- Earth Dam, 15’ high, 100’ long, one 24” concrete pipe outlet at base of dam without the following;
  - No engineering records on file or found.
  - Unattended dam without dam operator.
  - Inadequate principal spillway
  - No emergency spillway

APPLE VALLEY DAM FAILURE VIDEO - Begin @ 1.50-2:0m PLAY

Owens Marsh Dam Overtopping Failure

Owens Marsh Dam Failure

Owens Marsh Dam Failure

Road side-drain washout culvert 2

Washout of culvert 2

Erosion damage between culverts 2 & 3

Replacement of 3rd culvert 48” cmp

Owens Marsh Dam, Concord Township, Somerset County, ME.

- Type, Time and Date of Failure – Overtopping Breach - 3am - Monday July 17, 2000.
- Estimated breach flow 4,800 cfs
- Estimated Damage to road – $1,000,000 fixed by MDOT, one car but no loss of life.
- Antecedent conditions - 6 hour, 50 year storm starting Sunday, July 15, 2000 at 1pm.

- Probable failure mode – blocked primary spillway and riser – inadequate emergency spillway. The breach most likely initiated at the emergency spillway.

- Data – 10’ high, 101’ long, earth embankment, 70’ wide at base. Primary Spillway – 72’ long, 30/24” corrugated PVC pipe through base of dam with 7’ high, 30” PVC riser located 20’ downstream inlet. Water level controlled by stop-logs in PVC riser. Emergency spillway - 12’ wide t6” deep channel through embankment.

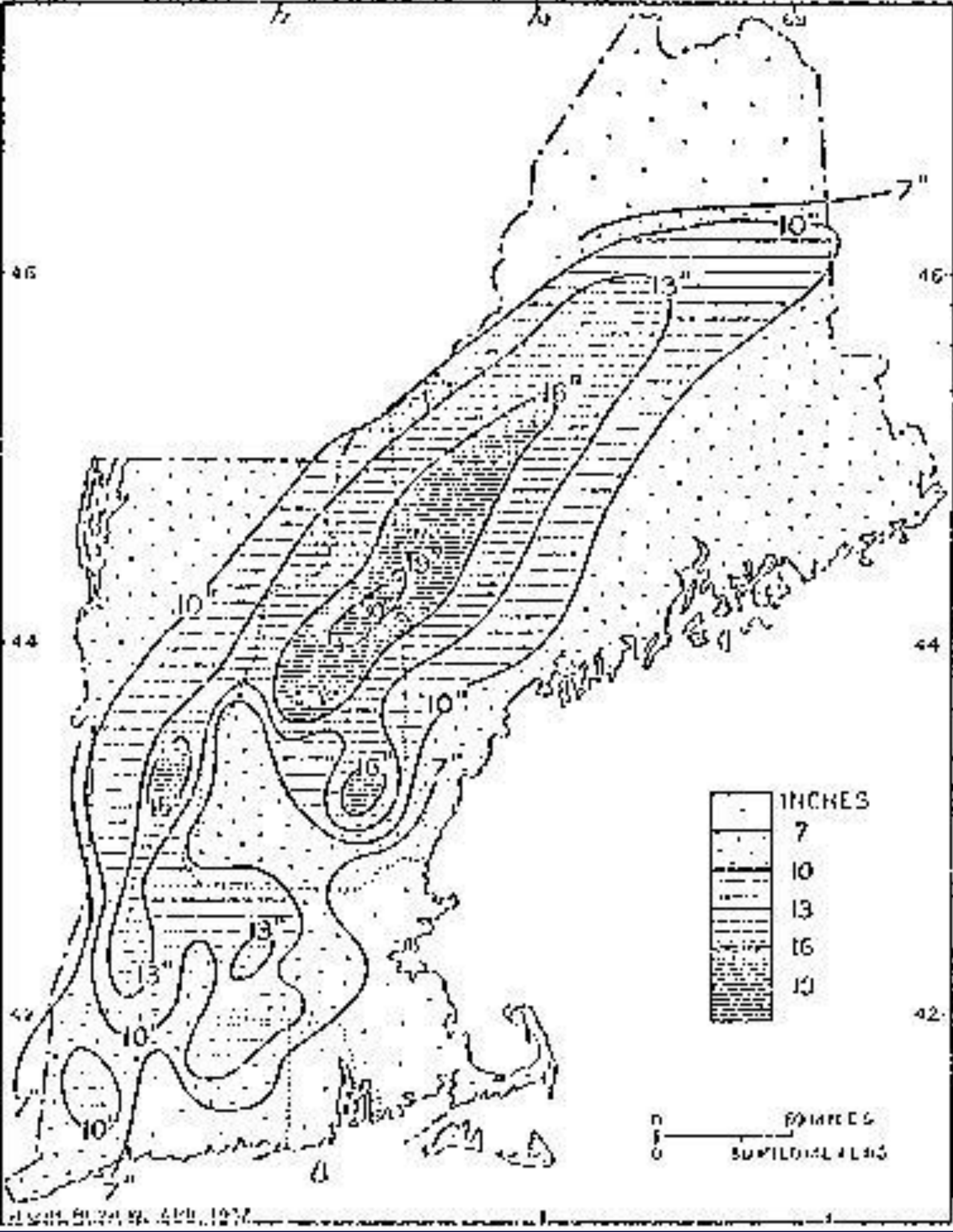
- Deficiencies - Not registered or inspected by MEMA before failure. No competent engineering design or supervision, earth dam with the emergency spillway flowing over the wall, plan based on standard drawing by Ducks Unlimited, unprepared foundation, constructed of local glacial silt, inadequately compacted. Uncontrolled beaver activity allowed in at principal spillway, no operation or maintenance plan.

Owens Marsh Dam Construction

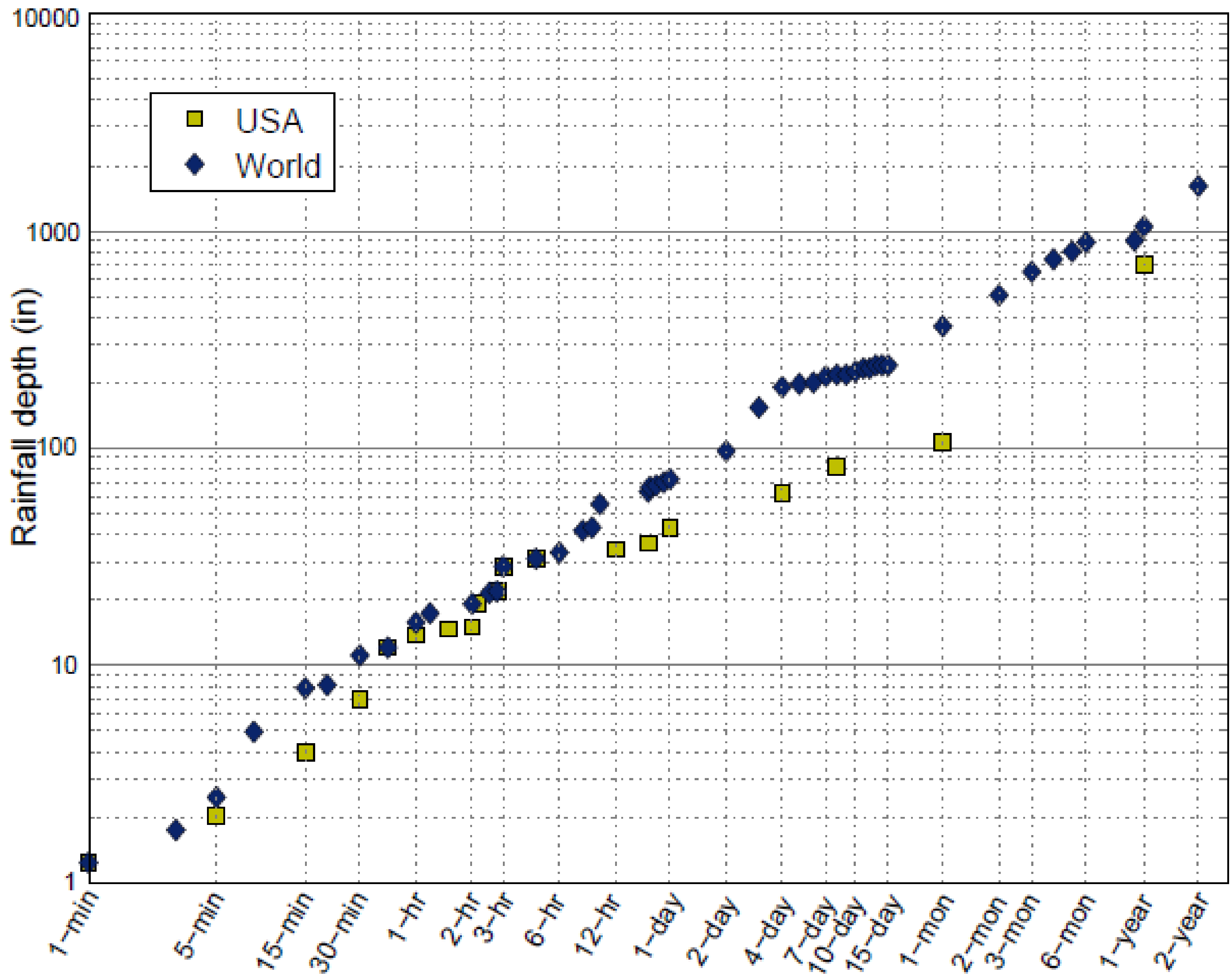
- 8/2/96 IFW proposed a 10' high, 30' wide, 120' long, earth dam, 490cy, plus 370cy remained from previously breached to restore a historic impoundment. Dam designed to operate 4' deep. US Army Corps of Engineers approved plan.
- Reconstructed "in-house" in 1996 by IFW using hired backhoe and bulldozer. Preparation included excavation to hardpan and ledge, removal of old beaver dam and placing mud, 8"-12" deep to surface the dam after construction.
- No site plan, site investigation, design details, specification or as-built construction records were found. Design plans found were minimal.
- Principal spillway constructed in black PVC pipe, based on a "Ducks Unlimited" design which assured; a) water control using stop-logs, b) beaver control at both inlets. IFW post breach memo 8/16/200 describes 6-10 cy "native clay" placed around "HiCore C pipe somewhere between the stand pipe and outlet.
- Emergency spillway, 12' wide x 12" open channel through top of right (north) dike.

Mill Dam, Lovell, ME (1937) - Overtopping Failure

Mill Dam, Lovell, ME (1937) – Downstream Flooding

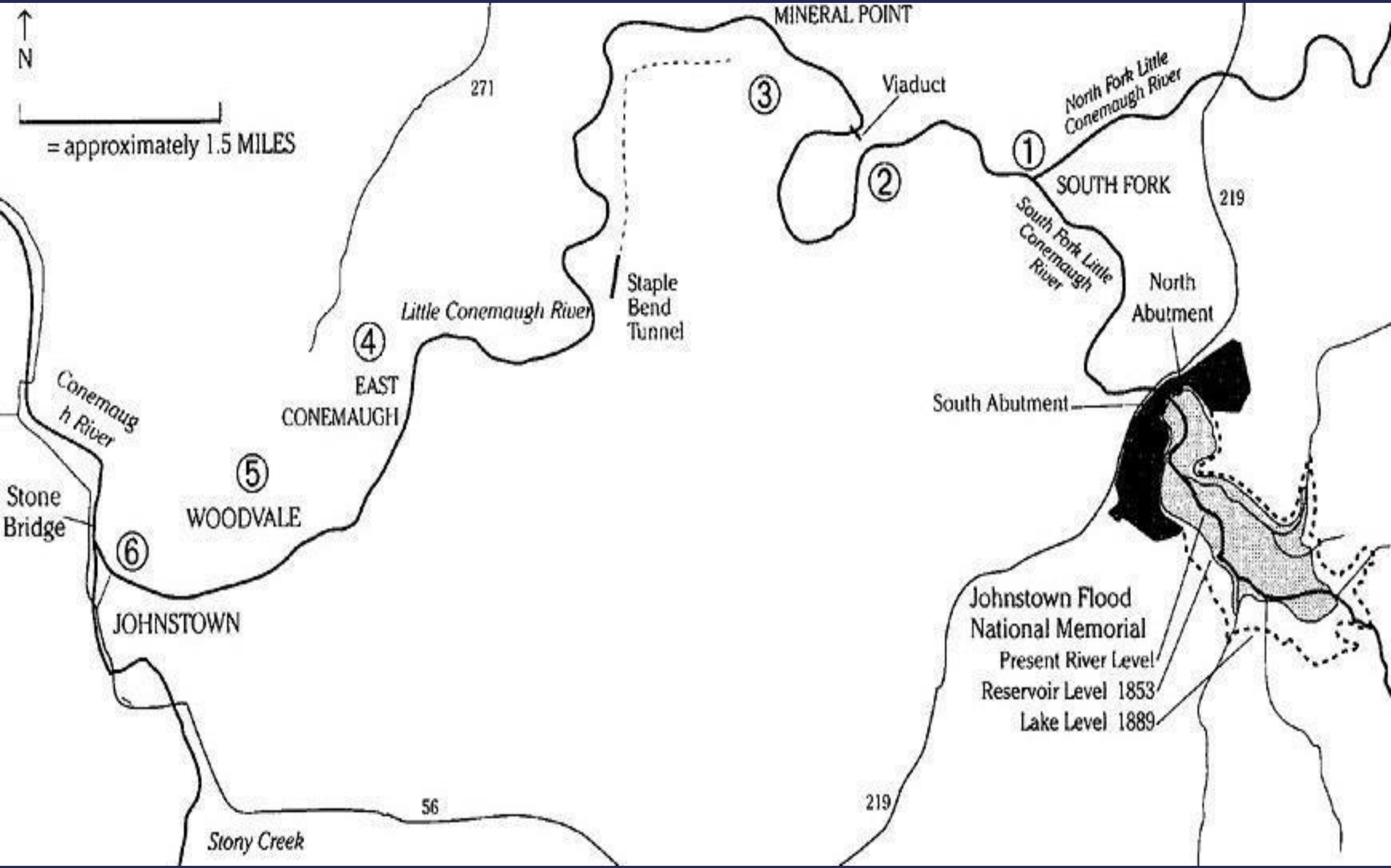


Rainfall distribution for the April 1937 Storm in Maine



10000
1000
100
10
1
Rainfall depth (in)
USA
World
1−min
5−min
15−min
30−min
1−hr
2−hr
3−hr
6−hr
12−hr
1−day
2−day
4−day
7−day
10−day
15−day
1−mon
2−mon
3−mon
6−mon
1−year
2−year

Southfork Dam, PA – Failed by Overtopping - May 31, 1889



At 4:07 pm on May 31, 1889, after several days of unprecedented rain, Southfork dam breached, sending a torrent of muddy water and debris downstream.

Death Toll - 2,209, Damage $17 million

1/3 Victims never identified

Cause – Inadequate spillway

The ruins of the South Fork Dam and Lake Conemaugh. The line at the top of the image shows where the dam had been.

South Fork Dam (PA)

72’ high, 931’ long, earth dam with a clay core, with five 24” CI outlet pipes in a brick culvert through its base, and a 88’ wide, 10’ deep, uncontrolled side-wash channel on the right located 8 miles from, and 450 feet above street level in Johnstown. Built by the Commonwealth of PA in 1838 to supply water to a canal system. Dam impounded the 400 acre Conemaugh Lake, of14,000 af (17 million tons). In 1853 the dam was sold to the Pennsylvania Railroad who abandoned it. In 1862 part of the culvert collapsed and a portion of the dam washed out.

In 1881 the dam was purchased by the Southfork Fishing and Hunting Club, who lowered the top of the dam for a road which reduced the reducing spillway discharge 30%. The operating level was also raised. Between 1881 and 1889 the dam frequently sprang leaks which were patched with mud and straw. Many false alarms about its failure raised concerns about its integrity, in particular by the head of the Cambria Iron Works in Johnstown. 3 of the 24” CI pipes has been removed and sold for scrap.

250 houses were wiped out in Woodvale, a small town upstream of Johnstown.

Johnstown was flooded in 30 minutes. The debris that had collected at the stone bridge caught alight, incinerating may people who had survived the initial flood. It was the worst disaster in U.S. history at the time. Relief efforts were among the first major actions of Clara Barton and the newly organized American Red Cross which she led.

Workers recovering a body from debris.

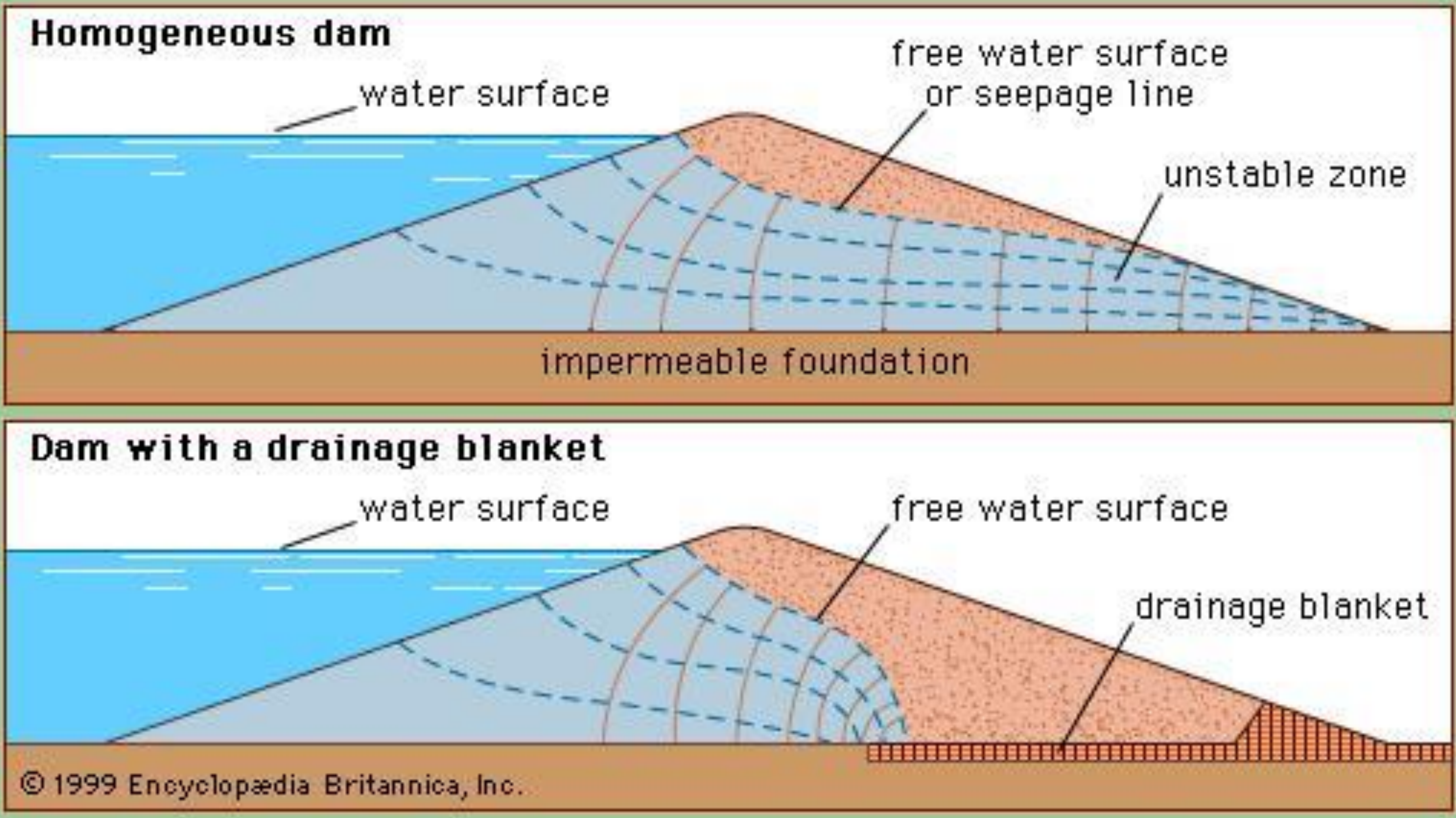
One of the hotels constructed by the American Red Cross to provide lodging to homeless flood survivors.

Seepage & Piping Failure

(Internal Erosion)

VIDEO-ASDSO-SEEPAGE & PIPING 1.17m

Seepage through an Earth Dam



Failure by Internal Erosion Caused by Seepage & Piping

Prevention of Overtopping

#891 Stanhope Mill Dam, Lincoln, Penobscot County, ME.

Overtopping averted by Dam Owner during spring runoff - April 16, 2014

Method used - Sandbagging

Dam defect highlighted - Inadequate Spillway


#891 STANHOPE DAM - May 14 1985
FREEBOARD

SANDBAGS ON STANHOPE DAM TO INCREASE FREEBOARD & SPILLWAY CAPACITY – April 16, 2014